

Description of two new pseudoposematic species with a review of defensive adaptations in the subfamily Thynninae (Hymenoptera: Thynnidae)

GRAHAM R. BROWN

Museum and Art Gallery Northern Territory,
GPO Box 4646, Darwin, NT 0801, AUSTRALIA
thynnini@hotmail.com

ABSTRACT

Two new species of thynnine wasps, *Lestricothynnus abispoides* and *Zaspilothynnus scolioides*, are described, the males of which are mimics in size and colour pattern of *Abispa* spp. (Hymenoptera: Vespidae) and *Scolia* spp. (Hymenoptera: Scoliidae), respectively. Defensive mechanisms found in the Australian Thynninae are reviewed, including newly discovered defensive pheromones and stridulation.

KEYWORDS. Hymenoptera, Thynninae, *Lestricothynnus*, *Zaspilothynnus*, Australia, pseudoposematic, defence pheromones, stridulation, colour patterns

INTRODUCTION

The Australian Thynninae contains about 600 described species with at least a further 1000 species yet to be described, but present in collections (pers. obs.). Little is known of the biology of the group although they are known to be parasites of scarab larvae (Ridsdill-Smith 1970) and the males of some are specific orchid pollinators (c.g. Bower 1996; Brown 1997a, b; Peakall 1990).

One of the most obvious features of the subfamily is the extreme dimorphism between the sexes. Males are fully winged and are typical wasps in appearance. Females are wingless and somewhat ant-like, but with stouter bodies and the legs partially spinose. This dimorphism has led to a dependence on the males for females to be flown to a food source such as nectar and hemipteran exudates (Given 1954). Strong but flexible coupling mechanisms (Brown 2000) enable pairs to remain in copula for prolonged periods including flight and feeding.

There has been nothing published on the defensive mechanisms within this group, however, as in all Hymenoptera (ants, bees and wasps), it is only the female that can sting using the ovipositor and associated venom glands. The ovipositor's primary function is to lay eggs, but in most Hymenoptera it is also used to paralyse prey or to inject venom as a defensive weapon against larger predators. Males sometimes attempt to "sting" by jabbing a predator with the apex of the abdomen, but males lack both an ovipositor and venom glands.

An examination of museum collections suggests that a number of thynnine wasp species bear a resemblance to paper wasps (Hymenoptera: Vespidae: Polistinae). The females of the latter possess a painful sting. The two Northern Territory thynnines described here are unusual

in that their colour patterns are both distinctive within the Australian fauna and that they bear a close resemblance to either potter wasps (Hymenoptera: Vespidae: Eumeninae) or hairy flower wasps (Hymenoptera: Scoliidae).

Other defensive strategies used by males, including stridulation and pheromones, are newly reported and discussed.

Terminology follows Snodgrass (1941), Brown (1997a, b) and Naumann (1991). Relative terms relating to microsculpture are interpreted as follows: sparsely punctate = punctures greater than two puncture-diameters apart; punctate = punctures at most two puncture-diameters apart, but never confluent; closely punctate = punctures almost confluent; rugosely punctate = punctures partially confluent; finely punctate = punctures small and shallow; coarsely punctate = punctures large and deep; obscurely punctate = punctures small, sparse, shallow and only visible at certain angles.

Abbreviations. Morphological characters: T1–7, metasomal tergites 1–7; S1–8, metasomal sternites 1–8. Specimen repositories: AM, Australian Museum, Sydney; ANIC, Australian National Insect Collection, CSIRO, Canberra; BMNH, The Natural History Museum, London (formerly British Museum (Natural History)); NTM, Museum and Art Gallery of the Northern Territory, Darwin (formerly Northern Territory Museum).

SYSTEMATICS

Lestricothynnus Turner, 1910

Type species *Thynnus nubilipennis* Smith, 1879, by original designation. Gender masculine.

Diagnosis. Males are distinguished by antennal prominence broadly rounded (rarely discontinuous

medially), broader than long, and flat (without raised margins) and the body including the metasoma usually extensively coloured; and females by the pygidium oblique, about 4 times longer than wide or longer, longitudinally multicarinate often slightly constricted, never spinose.

Wasps of this genus are medium to small. Typically males are black with yellow or orange markings including paired lateral spots on the abdominal segments and females orange to dark brown without yellow markings.

Remarks. Based on published records, the known distribution is in eastern and southern coastal regions of mainland Australia but discontinuous between north and south Queensland, and between the Eyre Peninsula of South Australia and south-western Western Australia. The genus has not been recorded previously from the Northern Territory.

Lesticothynnus abispoides sp. nov.

(Figs 1–4)

Type material (all Northern Territory). HOLOTYPE—AM, ♂, Stokes Creek, George Gill Range, 26–27 May 1983, G.A. Holloway. PARATYPES—AM, 5♂, same data as holotype; BMNH, 7♂, same data as holotype; NTM I.5374–I.5378, 5♂, same data as holotype; NTM I.5379–I.5380, 2♂, 8 km N of Alice Springs, 8 November 1979, G. Griffin; NTM I.5381, 1♀, Corroborree Rock Conservation Reserve, visiting *Melaleuca bracteata* flowers, 2 December 1993, G.R. Brown; ANIC, 2♂, 2♀, Todd River, 23°38'S, 133°53'E, 9 km NbyE of Alice Springs, on flowers of *Prostanthera striatiflora* F. Muell., 28 September 1978, J.C. Cardale; ANIC, 3♂, Entire Creek, 22°58'S, 135°09'E, 155 km NEbyE of Alice Springs, 13 October 1978, J.C. Cardale; NTM I.5382, I.5383, 2♂, Pinnacles Bore 23°14'S, 134°12'E, October 1995, J. O'Grady.

Description of male (Figs 1, 4). Body length 19–22 mm; fore wing 15–16 mm; hind wing 11–12 mm. Clypeus closely punctate; frons, vertex and gena finely and rugosely punctate; occipital and hyperstomal carinae well developed, visible and distinct in profile. Pronotum finely and rugosely punctate to transversely finely and rugosely punctate, anterior margin strongly carinate and produced laterally; mesoscutum rugosely punctate; mesoscutellum rugosely punctate, narrowly sagittally impunctate; metanotum rugosely punctate; propodeum transversely rugosely punctate; mesopleuron plus mesosternum rugosely punctate. Metasoma finely and rugosely punctate, punctures deeper and coarser on apical segments; S1 medially raised; epipygium rounded, transversely multicarinate carinate apically and abruptly produced into large transparent plate; hypopygium triangular with prominent apical spine and basal lobes, dorsal surface weakly transversely carinate. Genitalia: parameres (in profile) broad with ventral margin straight basally and angled ventrally towards apex which is subtriangular with apex rounded, dorsal margin expanded and broadly rounded over most of length, curved longitudinal line of

stout bristles on inner surface arising near ventral margin near level of apex of cuspides; digiti large and rounded; cuspides slightly longer than wide, broadly truncate apically, with vertically lamellate longitudinal process arising ventrobasally.

Colour. Mostly orange; mesoscutum, most of mesopleuron except dorsally, mesosternum, T3–4 and S3–4, all black. Wings orange, fore wing with large preapical black spot on costal margin.

Description of female (Figs 2–3). Body length 11 mm. Head subrectangular, wider than long, posterolateral angles broadly rounded; clypeus not sagittally carinate, broadly rounded apically; mandible with fringe of long setae on outer margin ventrally, long, curved, without notches or teeth; frons and vertex almost impunctate; gena sparsely punctate. Pronotum with dorsum subrectangular, wider than long, anterior margin convex, posterior margin weakly concave, impunctate except for a few setiferous punctures at anterolateral angles, setae long; lateral surfaces impunctate. Mesoscutellum impunctate. Propodeum impunctate; lateral margin sharply defined ventrally, less so dorsally; dorsal surface flat, short and wide, wider posteriorly; posterior surface flat and oblique. Metasoma longer than head and mesosoma combined, sparsely punctate on tergites and closely punctate on sternites, segments 2–3 widest; T2 with 6 transverse carinae (including apical and basal), carinae continuous across tergite and not branched; S5 strongly longitudinally carinate, carinae becoming curved outwards posteriorly, closely and coarsely punctate basally. Pygidium (Fig. 3) oblique with lateral margin gradually and slightly converging ventrally, longitudinally multicarinate.

Colour. Mostly yellow; head posteriorly, legs, posterior margin of T1–5 narrowly, pygidium except medially, and sternites, all orange; apex of mandibles, most of mesopleuron and lateral surface of propodeum except dorsal margin and broad medial transverse on pygidium, all brown.

Distribution. Ranges of central Australia in the vicinity of Alice Springs (24°20'S, 131°44'E).

Etymology. The specific name is a reference to a similarity with potter wasps (Vespidae: Eumeninae) of the genus *Abispa* Mitchell (Fig. 4). It is intended as a noun in apposition.

Remarks. This species is not closely related to the type species, *Lesticothynnus nubilipennis* (Smith) which is mostly smooth, polished, and sparsely and shallowly punctate, or any other in the genus. The colour pattern is distinctive and atypical.

The male shows some similarity to *L. constrictus* (Smith) in having a more fusiform metasoma but the latter does not have the epipygium transversely multicarinate. The female differs from *L. constrictus* in that the pygidium is broader dorsally rather than *vice versa*. The sexes were associated by coincident collecting data.



Figs 1–4. *Lesticthynnus abispoides* sp. nov.: 1, male; 2, female; 3, female pygidium; 4, male (left, mimic) contrasted with *Abispa ephippium* (right, model).

***Zaspilothynnus* Ashmead, 1903**

(Figs 5–12)

Type species *Thynnus leachiellus* Westwood, 1844, by monotypy. Gender masculine.

Diagnosis. Males are distinguished by the combination of posterolateral spines on S6 and the epipygium produced into a subapical plate; and females by an oblique pygidium which is laterally exaevate and at least partially transversely or obliquely carinate dorsally but not long and narrow or star-shaped (4-pointed). (Note: it is currently not possible to distinguish this genus from *Leptothynnus* Turner, 1910 or *Pogonothynnus* Turner, 1910, which may or may not be junior synonyms.)

Wasps of this genus are large (body length up to 24 mm). They are usually brightly coloured and many are stout bodied. Less often they are black or mostly so. The Northern Territory species (as well as *Z. cheesmanae* Turner from New Guinea) are rather distinctive in that they have coloured rather than hyaline (or weakly infuscate) wings.

Remarks. This genus is one of the most speciose genera of flower wasps. It contains 37 described species and an unknown number of undescribed species. It is most abundant in eastern and south-western Australia. Four

additional species (or subspecies) occur in New Guinea and a single species on Lord Howe Island off the coast of New South Wales (pcrs. obs.). There are no species recorded from Tasmania and only two previously, *Z. rhynchioides* Turner (Fig. 5) and *Z. ochrocephalus* (Smith), from the Northern Territory.

***Zaspilothynnus scolioides* sp. nov.**

(Figs 6–12)

Type material (all Northern Territory). HOLOTYPE – NTM I.5384, ♂, Casuarina Coastal Reserve near Darwin, 12°21'S, 130°52'E, rainforest, 4 October 1997, G.R. Brown. PARATYPES – ANIC, 1♂, same data as holotype; BMNH, 1♂, same data as holotype; NTM I.5385–I.5387, 3♂, same data as holotype; QM, 1♂, same data as holotype; WAM, 1♂, same data as holotype; NTM I.5388–I.5399, 12♂, same data as holotype, but dated 24 October 1995; NTM I.53400–I.53407, 8♂, same data as holotype, but dated 5 November 1995; NTM I.5408–I.5411, 4♂, same data as holotype, but dated 12 November 1995; NTM I.4412–I.5417, 6♂, same data as holotype, but dated 19 November 1995; NTM I.5418–I.5419, 2♂, same data as holotype, but dated 14 September 1996; NTM I.5420–I.5427, 8♂, same data as holotype, but



Figs 5-8. Similar-looking wasps showing poseuapomorphic colour patterns: 5, *Zaspilothynnus rhynchioides*, male; 6, *Zaspilothynnus scolioides* sp. nov., male (left, mimic) contrasted with *Scolia verticalis* (right, model); 7, *Zaspilothynnus scolioides* sp. nov., male; 8, *Zaspilothynnus scolioides* sp. nov., male.

dated 26 October 1996; NTM I.5428, 1♂, same data as holotype, but dated 29 September 1996; NTM I.5429, 1♂, same data as holotype, but dated 18 October 1997; NTM I.5430, 1♂, same data as holotype, but dated 19 October 1997; NTM I.5431-1.5434, 4♂, same data as holotype, but dated October 1997, ANIC, 1♂, same data as holotype, but dated 1 November 1997; BMNH, 1♂, same data as holotype, but dated 1 November 1997; NTM I.5435, 1♂, same data as holotype, but dated 1 November 1997; QM, 1♂, same data as holotype, but dated 1 November 1997; WAM 1♂, same data as holotype, but dated 1 November 1997; NTM I.5436-1.5465, 34♂, same data as holotype but dated 8 November 1997, S.M. Gregg; NTM I.5466-1.5476, 11♂, Buffalo Creek, near Darwin, Casuarina Coastal Reserve, sweeping between beach and road, 20 October 1996, G.R. Brown; NTM I.5477, 1♂, Casuarina Beach, 21 October 1991, A. Wells; NTM I.5478, 1♂, Oenpelli, 12°23'S, 133°05'E, November 1996, G.R. Brown.

Additional (non type) material (all Northern Territory): SAM (1♂), Darwin, W.K. Hunt; QM (1♂), Port Darwin, H.W. Brown; SAM (1♂), Groote Eylandt, N.B. Tindale.

Description of male (Figs 6-9). Body length 18-24 mm; fore wing 15-22 mm; hind wing 11-18. Clypeus finely

longitudinally striate sparsely overlaid with punctures; frons closely punctate becoming longitudinally rugosely punctate on antennal prominence; vertex almost impunctate; gena closely punctate. Pronotum impunctate, anterior margin with low narrow carina; mesoscutum impunctate except a few scattered punctures anteriorly; mesoscutellum and metanotum sparsely punctate; mesoscutellum sagittally raised and obscurely produced into small knob posteromedially; propodeum with short impunctate dorsal surface and long oblique rugosely punctate surface, lateral surface rugosely punctate; mesopleuron plus mesosternum impunctate becoming finely and closely punctate ventrally and anteriorly. Metasoma with tergites punctate and sternites closely to rugosely punctate; S1 medially raised with a weak posteromedial knob; posterolateral spines on S6 long, digitate and directed posteriorly; epipygium with well defined and strongly longitudinally carinate preapical plate, excavate below this plate and becoming membranous apically; hypopygium 5-spined, basal and lateral spines lobe-like, dorsal surface strongly transversely multicarinate. Genitalia: parameres (in profile) long, narrow and straight, ventral margin curved basally, dorsal margin sharply angled near level of apex of digiti with small notch



Figs 9–13. *Zaspilothynnus scolioides* sp. nov.: 9, male terminalia, dorsal; 10, female; 11, female; 12, female, pygidium; 13. *Rhyothemis phyllis*.

basad to this angle, apex rounded, line of stout bristles on ventral margin near apex; digiti small, rounded and visible in profile through small basal notch in paramere; cuspides not reaching to midlength of aedeagus, subtriangular becoming laterally compressed and upturned and almost digitate distally, slightly expanded at apex which visible in profile, ventral margin with long outwardly curved digitate process arising basomedially.

Colour. Black, with inner and outer orbit of eyes narrowly (but broadly interrupted at summit of eye), anterior margin of pronotum broadly, and T5, all yellow. Wings black with iridescent blue reflections, extreme tip of the fore wing hyaline which fully exposes black tip of metasoma. Setae black; white on frons and base of clypeus; brown on anterior surface of tibiae and tarsi. Head, body and appendages, including wings, polished.

Description of female (Figs 10–12). Body length 13 mm. Head subrectangular, wider than long, slightly wider dorsally than ventrally; clypeus sagittally carinate, rounded apically; mandibles long, strongly curved with small notch on inner margin at mid-length; frons deeply punctate, punctures closer on antennal prominence; vertex almost impunctate, becoming closely punctate posteriorly;

gena punctate. Pronotum with dorsum subrectangular, wider than long, anterior and posterior margins weakly concave, lateral angles slightly produced, closely and finely punctate becoming less so medially and posteriorly, reticulate; lateral surfaces impunctate and reticulate. Mesoscutellum sparsely punctate. Propodeum with lateral margins sharply defined; dorsal surface flat, short and wide, wider posteriorly, sparsely punctate; posterior surface flat, oblique and very finely punctate dorsally; lateral surfaces polished and impunctate. Metasoma longer than head and mesosoma combined, punctate, punctures deeper on tergites, segments 1–4 the widest; T2 transversely multicarinate, carinae continuous across tergite and becoming finely branched near their lateral extremity; S5 strongly longitudinally carinate, carinae becoming curved outwards posteriorly. Pygidium (Fig. 13) subparallel basally becoming expanded posteriorly into broadly ovate surface that is deflexed and almost vertical; transversely carinate, becoming curved and vertically carinate on dorsal half of posterior ovate surface which is smooth and polished on ventral half.

Colour. Dark brown, almost black.

Distribution. Coastal Northern Territory between Darwin and Groote Eylandt.

Etymology. The specific name is a reference to a similarity with hairy flower wasps (Scoliidae) of the genus *Scolia* Fabricius. It is intended as a noun in apposition.

Remarks. Yellow colouration on pronotum of the male is variable, and may be reduced to large anterolateral spots, or frequently absent. In life and when the wings are closed and at rest, the yellow on T6 is just hidden by the end of the dark colouring of the fore wing, and the hyaline apex of the tip of the fore wing only exposes the black tip of the abdomen to dorsal view.

This new species is closest to *Z. rhynchioides* Turner on the basis of size, the polished body, metasomal shape and the medially raised mesoscutellum. However, the latter species has the metasoma shorter, the head, pronotum and apical three segments of the metasoma uniformly orange, and the wings suffused with orange with the bases and the apex of the fore wing infusate, and the hypopygium subtriangular with lateral margins emarginate. There is also some resemblance to *Z. ochrocephalus* (Smith), but this is larger and not polished, and has the metasoma uniformly black, conical, and closely punctate rather than polished. The female is not closely related to any other species, although those of *Z. rhynchioides* and *Z. ochrocephalus* are currently unknown.

The species described here is easily recognised by its dark blue-black wings like those of scoliid wasps of the genus *Scolia* (Fig. 6).

In Darwin the males are on the wing for a little over two months from late September to early December. The only known female was collected at Casuarina Coastal Reserve in copula and in flight. Separated from the male, it strongly attracted additional males into an open car park well away from the monsoon vine thicket it had inhabited. At another site (Buffalo Creek), it strongly attracted males into a vehicle.

DISCUSSION

Little is recorded about the biology of the Thynninae, and nothing about defensive mechanisms other than a few species being mimics of paper wasps (Vespidae: Polistinae). The distinctive pseudaposematic colour patterns of the two species described here prompts a fuller discussion of mimicry and other presumed defensive mechanisms within the subfamily Thynninae.

Colour. In the Australian thynnine fauna, females are usually uniformly brown, but may range in colour from orange to almost black. Occasionally they are marked with yellow or orange (especially larger species such as those found in *Thynnus* Fabricius and some *Catocheilus* Guérin and *Zaspilothynnus*). This colour pattern is advantageous when females are walking on the surface of the ground and when they are most vulnerable to predators.

The colour patterns of the males are usually more conspicuous and complex. The basic patterns can be grouped as follows:

1. Black with no yellow markings – *Dimorphothynnus* Turner, *Rhagigaster* Guérin, *Rhytidothynnus* Brown and *Umbothynnus* Brown only, however there are some species within the genera *Ariphron* Erichson, *Phymatothynnus* Turner and *Tachyphron* Brown as well as others that are also uniformly black or show slight traces of yellow, especially on the clypeal margin, antennal prominence, pronotal margins and mesoscutellum;

2. Black and extensively marked with yellow including: the margins and much of the disc of the clypeus, antennal prominence, orbits of the eyes, anterior and posterior margins of the pronotum, central mark and lateral line on the mesoscutum, mesoscutellum, disc of metanotum, 2–3 longitudinal marks on propodeum, anterodorsal and anteroventral spots on mesopleuron, margins of mesosternal lamellae, marks on the legs (especially the coxae), paired spots on each tergite and sternite (although reduced in size, or absent, on anterior and posterior segments). The yellow markings are variable within the following extremes: they may be more extensive including enlargement of the metasomal spots are enlarged to form transverse bands or to completely colour the sclerite; or they may be reduced and limited to the margins of the antennal prominence, the anterior margin of the pronotum; and the mesoscutellum. Most genera are placed here; and

3. Black with some sclerites mostly yellow or orange (rather than spotted or narrowly margined) – occurs in some *Eirone* Westwood only. However, some species within the genera *Campylothynnus* Turner, *Catocheilus*, *Elidothynnus* Turner, *Macrothynnus* Turner, *Thynnus* and *Zaspilothynnus* have the paired abdominal spots so enlarged and confluent that they form bands on, but unlike *Eirone*, have other markings consistent with group 2.

Apparently independent of these three basic colour patterns are the colour of the antennae, legs, wings, the presence of brown lateral spots on the vertex and red on the metasoma or mesopleuron. These also appear to be independent of each other (although species with orange antennae often have orange or yellow legs), and are as follows:

a. Antennae brown or orange (usually black) – occurs in some species and is not genera-specific;

b. Black on the legs may be replaced by orange or red (but usually excluding the coxae) – occurs in some species and is not genera-specific;

c. Wings usually hyaline to weakly infusate, rarely spotted in most *Lestricothynnus* and *Tachynoides* Kimsey and rarely black as in some *Belothynnus* Turner, *Rhagigaster*, *Thynnoides* Guérin, *Thynnus* and *Zaspilothynnus*;

d. Brown lateral spot on vertex – occurs in *Aeolothynnus* Ashmead and some related genera, and is of some generic value;

e. Metasoma red (except bases of T1 and S1) or apical 2 segments red. Occurs in some species of *Dimorphothynnus*, *Iswaroides* Ashmead, *Lophocheilus* Guérin, *Rhagigaster* and *Zaspilothynnus*; and

f. Mesopleuron uniformly red (usually black, or black with yellow marks, or black replaced with orange) – occurs in some species of *Dimorphothynnus*, *Rhagigaster* and *Thynnoides*.

Mimicry. A number of species, particularly some species within the genera *Leiothynnus* Turner, *Epactiothynnus* Turner, *Lestricothynnus* and *Zythynnus* Kimsey resemble vespid wasps (Hymenoptera: Vespidae) of the genera *Polistes* Latreille and *Ropalidia* Guérin. Polistine wasps are social, may occur in large numbers, and possess a painful sting. This mimicry is particularly enhanced in *Lestricothynnus* by the presence of a small spot near the pterostigma which occurs in many *Polistes*. This mimicry is most common in eastern Queensland.

Colour pattern 3 possibly mimics potter wasps (Vespidae: Eumeninae) but the resemblance is slight and the two groups are rarely collected at the same time. The colour pattern of *L. abispoides* however, strongly resembles potter wasps especially those of the genus *Abispa* which are similar-sized and occur widely in Australia including central Australia. The libellulid dragonfly *Rhyothemis phyllis* Lieftinck (Fig. 13), which has black and orange banding the base of the hind wing, also resembles *Abispa* when the dragonfly is flying rapidly to escape a predator.

Black wing colour may mimic that found in the hairy flower wasp genus *Scolia*. *Zaspilothynnus scolioides* strongly resembles this genus of wasps in size, and wing and body colour.

Alarm Pheromones. Insects produce a wide variety of pheromones which serve different functions. Within the Hymenoptera different pheromones are used as sex attractants, trail markers, alarm signals, recruitment to new sites or new food sources, and to stimulate regurgitation in social species (Naumann 1991). These are produced in the mandibular gland and may consist of a mixture of chemicals.

The males of Thynnini, especially the higher Thynnini (referred to as cluster one in Brown (2001)) and including *Lestricothynnus* and *Zaspilothynnus*, produce a pungent odour when handled. This odour is particularly noticeable when specimens are removed from the net by hand, and is present on the fingers after the wasp has been released from the hand. Although the chemical nature is unknown, it is almost certainly defensive and presumably repellent or distasteful. The odour is more distinctive in larger species, but is not strongly offensive to humans. This odour has not previously been recorded in the Thynninae.

Pseudo-stinging. Only female wasps sting, and some of these can be quite painful. For this reason many serve as models in Batesian mimicry systems (Quicke 1986) with mimics including hoverflies (Syrphidae), soldierflies (Stratiomyidae), robberflies (Asilidae), beetles

(Bombyliidae), clearwing moths (Sesiidae) and longicorn beetles (Cerambycidae), as well as other wasps. This includes the two new species described here.

While Batesian mimicry is most frequently seen in the form of similarities in colour, it can be behavioural in the form of a pseudo-sting, or pseudo-stinging behaviour.

The pseudo-stinging apparatus resembles the ovipositor of a female wasp. It may be in the form of pointed parameres or other parts of the male genitalial capsule, or other pointed processes that vary between taxa. In male Scoliidae the hypopygium (subgenital plate) has three long apical spines, while those in Thynnidae vary from none to five spines (Fig. 9).

Pseudo-stinging is a behaviour in which male wasps attempt to sting, even though there is no stinging mechanism present. This behaviour is strong in male scoliids when they are handled, and in larger specimens the apical spines do occasionally pierce the skin. In thynnids this behaviour may also be vigorous especially in larger specimens, but the spines are smaller and blunter, and cannot pierce the skin (although the mandibles sometimes can do so in larger species). Although many thynnids have weak or occasionally no spines, they all use this pseudo-stinging behaviour.

Stridulation. Stridulation and other forms of sound production are well known within the order Hymenoptera (Naumann, 1991). This includes rubbing wings against roughened lobes (cenchri) on the metanotum in some sawflies (Pergidae), a loud buzzing by some bees (Apidae), mud daubers (Sphecidae) and potter wasps (Vespidae: Eumeninae), and stridulation in some ants (Formicidae) and velvet ants (Mutillidae). However, little is known about why insects produce sound. It has been suggested that loud buzzing by mud daubers during mud collection helps to compact the mud. However, it could also be a deterrent to predators as similar sounds are produced in other groups such as bees which do not collect mud.

Ants, which have a complex social structure, use a variety of communication systems including chemical, visual and tactile methods, as well as drumming and stridulation. The latter is produced by raising the gaster causing a file on the third metasomal segment to rub against a plectrum on the second segment. These structures are usually located dorsally (Hölldobler and Wilson 1990).

A similar stridulatory mechanism occurs in velvet ants between the second and third metasomal segments, but on the ventral surface. Stridulation occurs in both sexes during mating and when individuals are disturbed (Manley 2000).

Males of the Australian genera *Dimorphothynnus*, *Eirone*, *Rhagigaster*, *Rhytidothynnus* and *Umbothynnus* (Rhagigasterini) stridulate when they are held with the fingers. This sound is audible and is produced by extending and contracting the metasoma. A dissection of males has not revealed any specialised internal structures on the sclerites, but sound can be generated in freshly killed specimens by

moving the metasoma in and out manually with the hands. This may be similar to that reported in mutillids (Manley 2000), but I can find no evidence of a basal file on T3 as in mutillids or on any other metasomal sclerite. This sound is a squeaking noise with a frequency of about two cycles per second.

It is not known if stridulation occurs in the Neotropical rhagigasterine genus *Aelurus*, but it does not occur in any other genus I have collected, and it does not occur in the females.

Sound production is probably defensive in thynnines as it has only been observed when wasps are held by the mesosoma by the fingers.

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